A Spill Management Information System for Freshwater Incidents

Edsel B. Daniel, James P. Dobbins, Paul H. Martin,
Eugene J. LeBoeuf, Mark D. Abkowitz

Vanderbilt University
Department of Civil and Environmental Engineering

in conjunction with

The Nashville District and the Engineering Research and Development Center, U.S. Army Corps of Engineers

Presentation Outline

- Background
- Project Objectives
- Conceptual Design and System Architecture
- Water and Air Quality Models
- Model Execution
- Spill Scenario Example
- Project Accomplishments
- Current and Future Work

Background

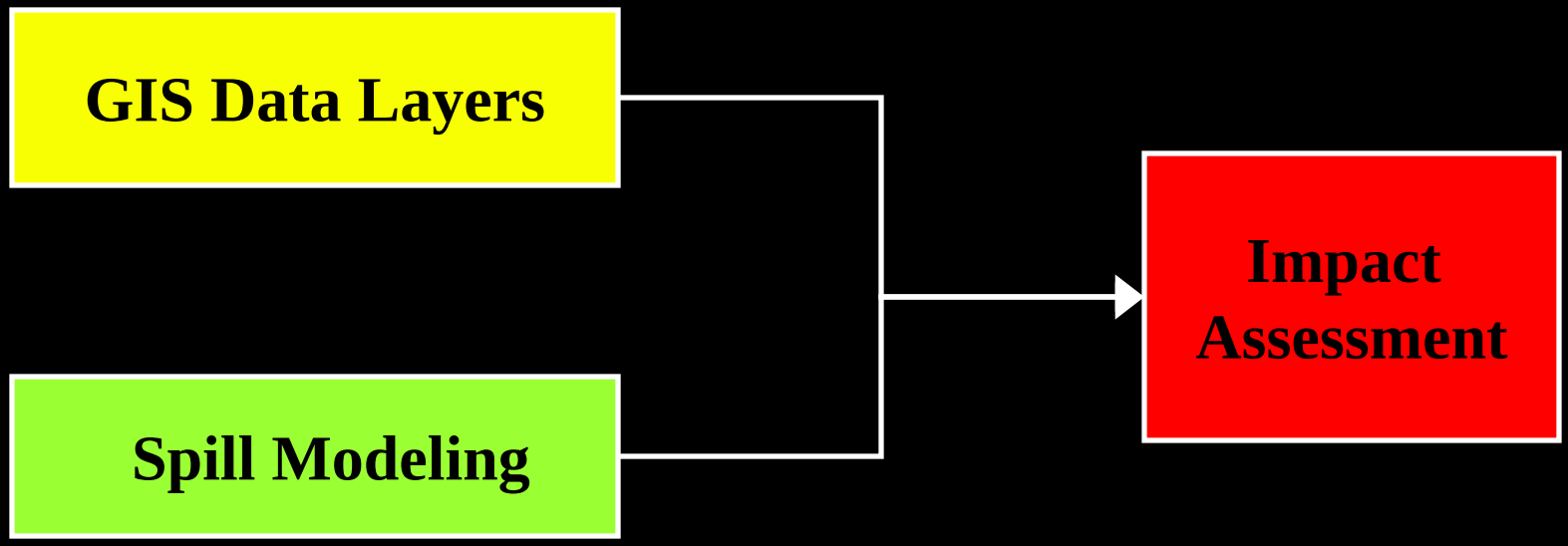
- U.S. Army Corps of Engineers (USACE) maintains over 11,000 miles of navigable waterways which include numerous critical marine elements:
  - Water supply, recreation areas, and sensitive environmental areas
- Marine transportation is considered one of the nation's most efficient, safe, and economical modes of freight transport.
- Hazardous materials comprise a large portion of barge transported commodities, placing communities along navigable waterways at risk of exposure to toxic chemicals in the event of a collision, grounding, or terrorist action.
- Managing a navigable water body chemical spill response involves coordination and communication among numerous federal, state, and local entities posing challenges in the areas of:
  - Retrieving characteristic chemical data
  - Jurisdictional responsibility of responding agencies
  - Location of waterway access points
  - Community notification

Project Objectives

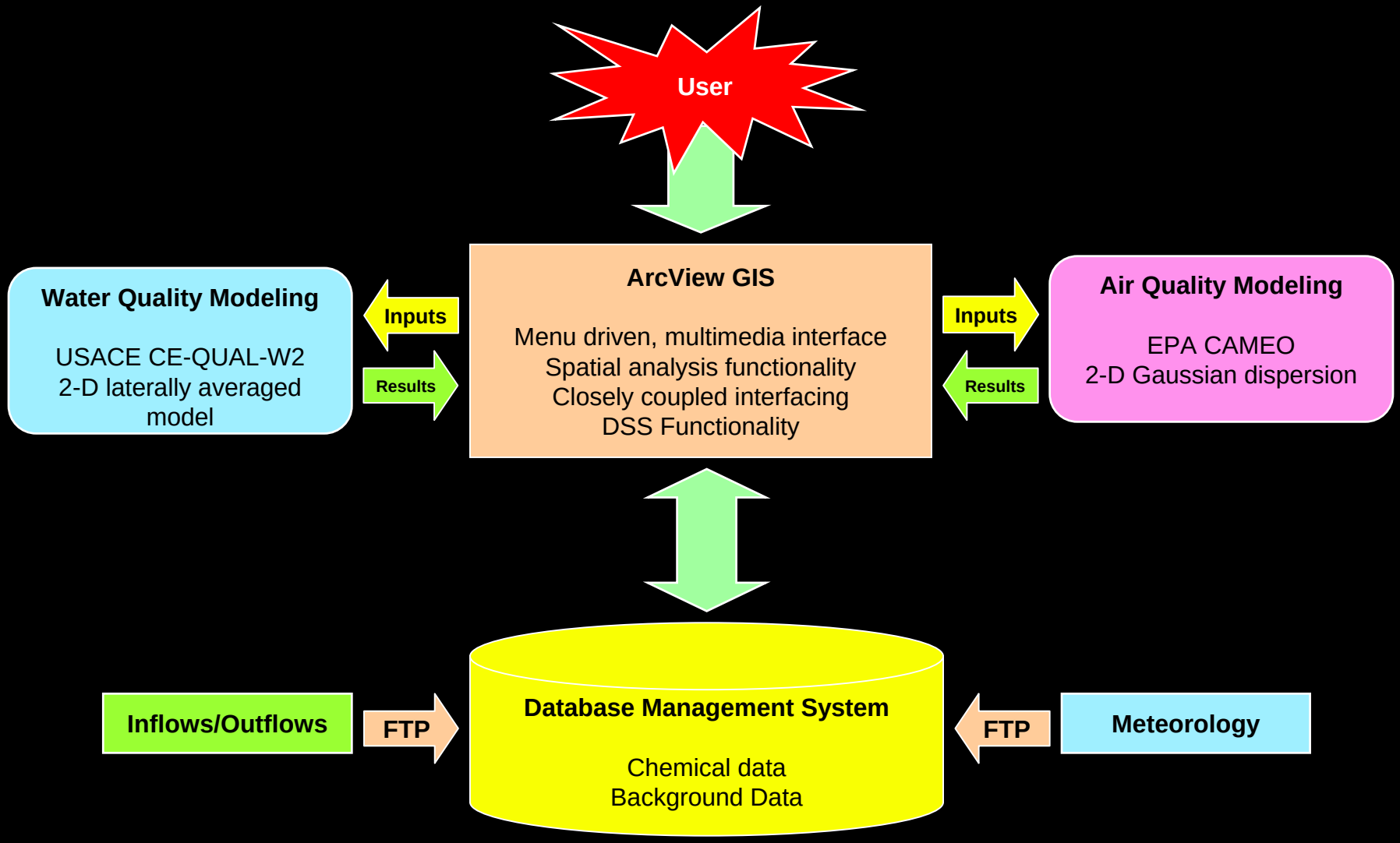
Develop a spill management information system (SMIS) that:

- **Addresses accidental releases and terrorist incidents**
- **Provides the capability to perform simulation training, contingency planning, and real-time incident management**
- **Utilizes advanced information technologies to deliver timely and accurate information in a spatial-based framework**

Conceptual Design

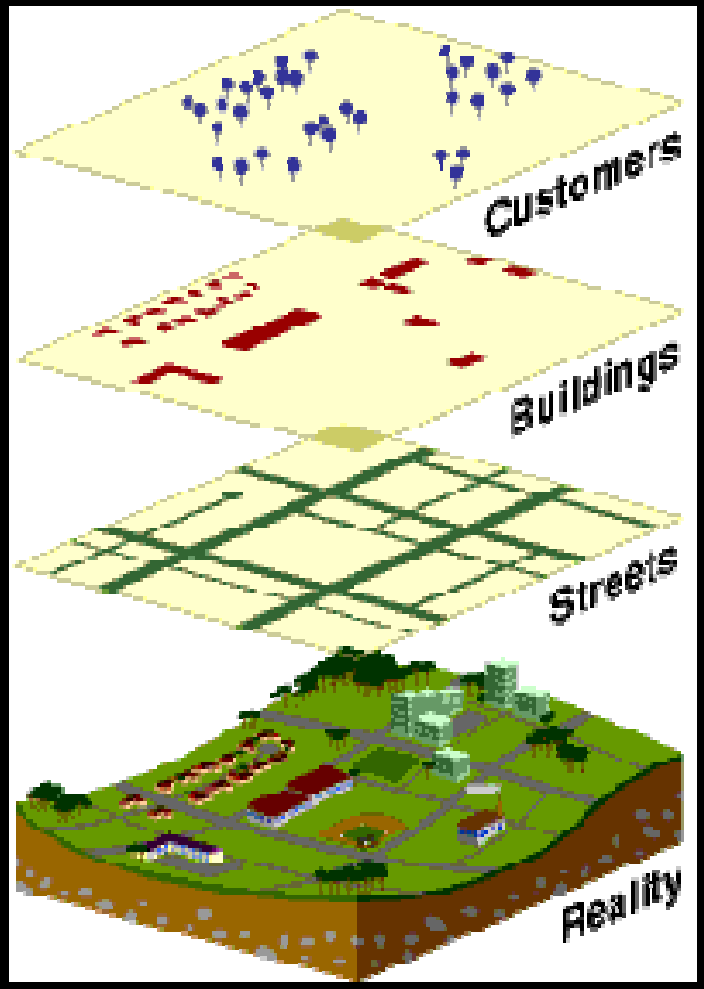


System Architecture



Geographic Information Systems

GIS is a system of computer software, hardware, and data to help manipulate, analyze, and present information that is tied to a spatial location.

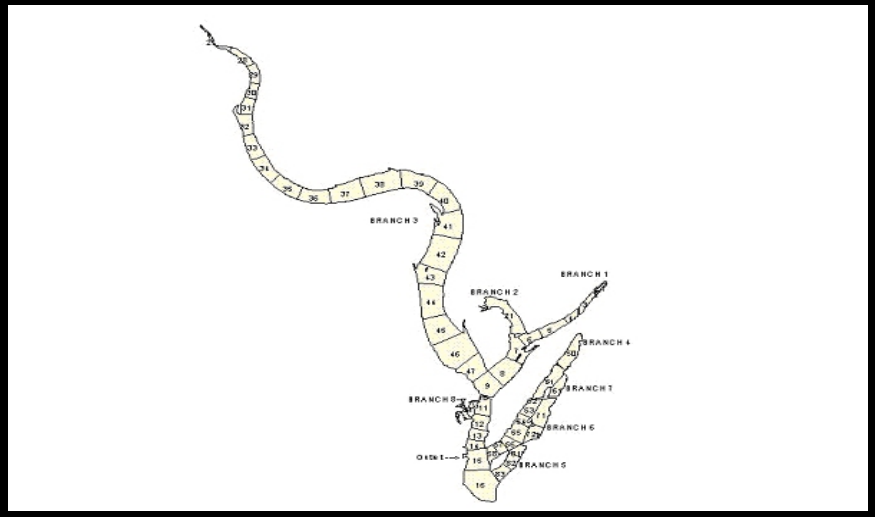


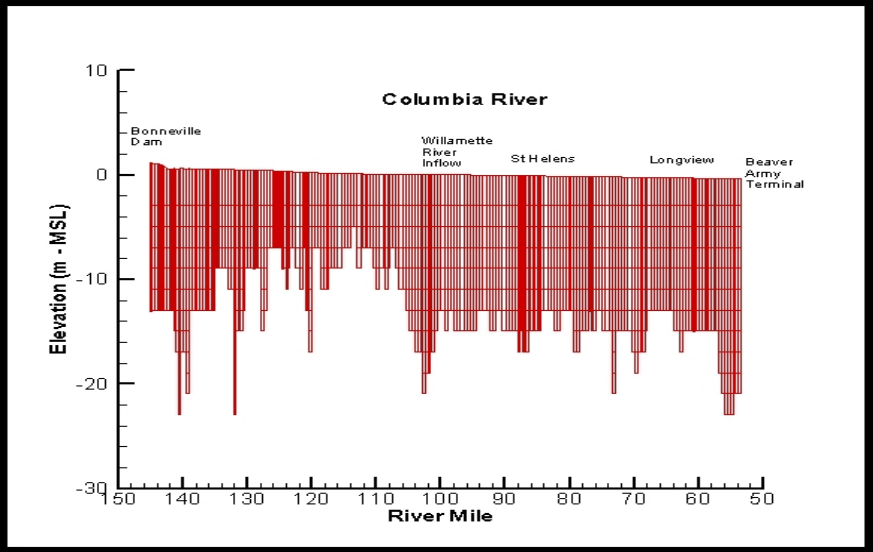
CE QUAL W2

2-D, longitudinal/vertical hydrodynamic and water quality model applicable to rivers, lakes, reservoirs, and estuaries.

Developed by Portland State University in conjunction with USACE Waterways Experiment Station (WES).

Version 3.1 developed for the Cheatham Reach of the Cumberland River.





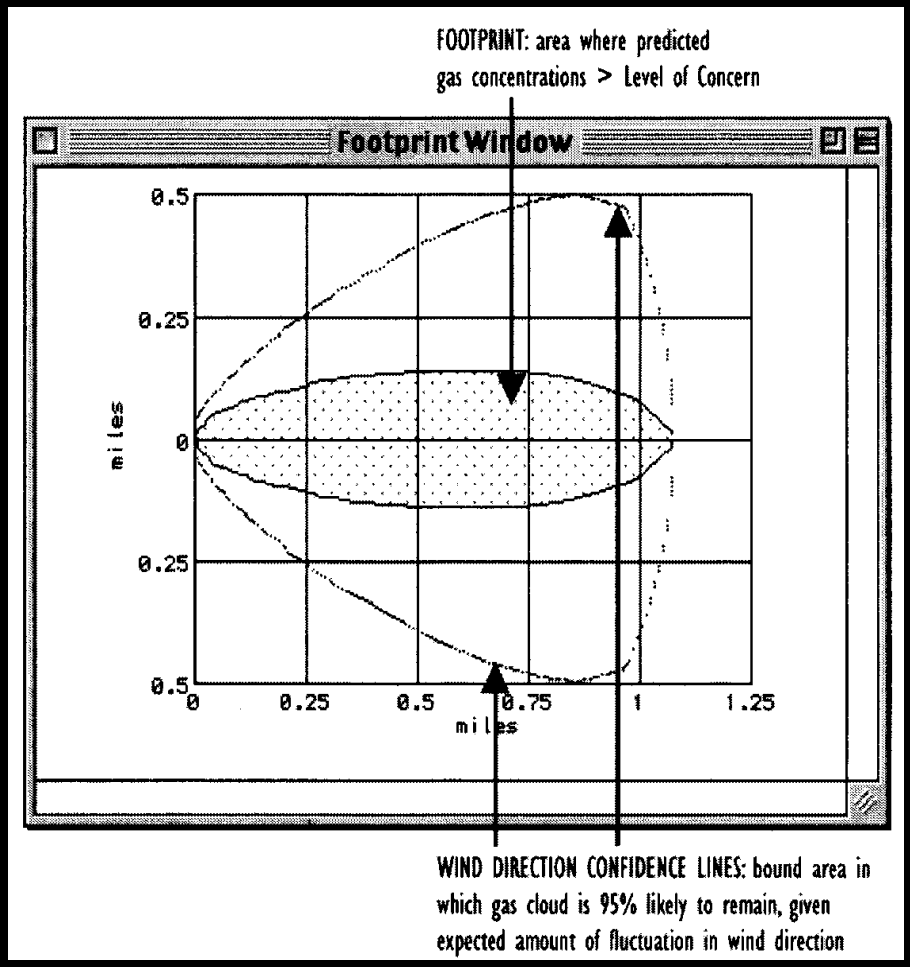
CAMEO

Computer Aided Management of Emergency Operations (CAMEO).

Suite of software programs used to plan for and respond to chemical emergencies developed by the USEPA and NOAA.

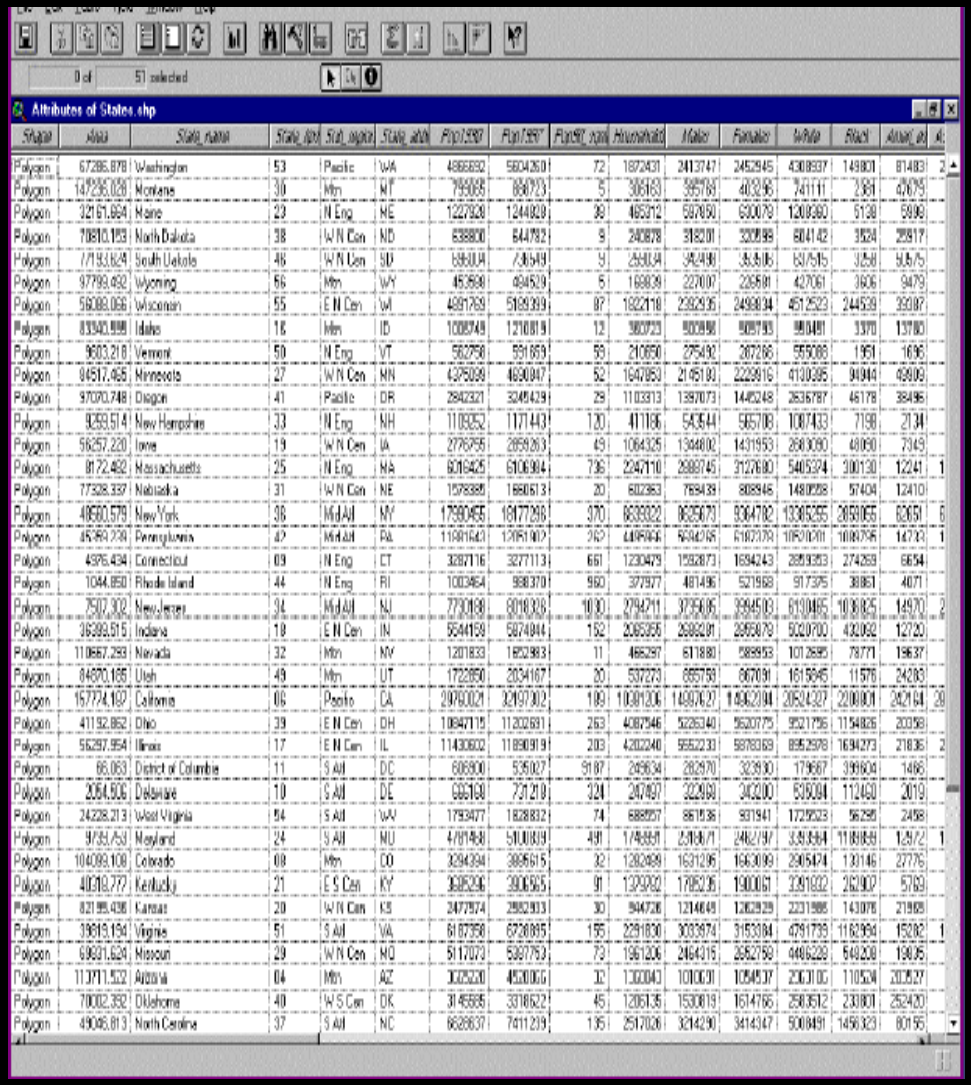
Includes a Chemical Library, Areal Location of Hazardous Atmospheres (ALOHA) and Mapping Applications for Response, Planning, and Operational Tasks (MARPLOT).

Generates a 'cloud footprint', encompassing the area where ground level concentration of a pollutant gas exceeds a pre-determined Level of Concern (LOC)

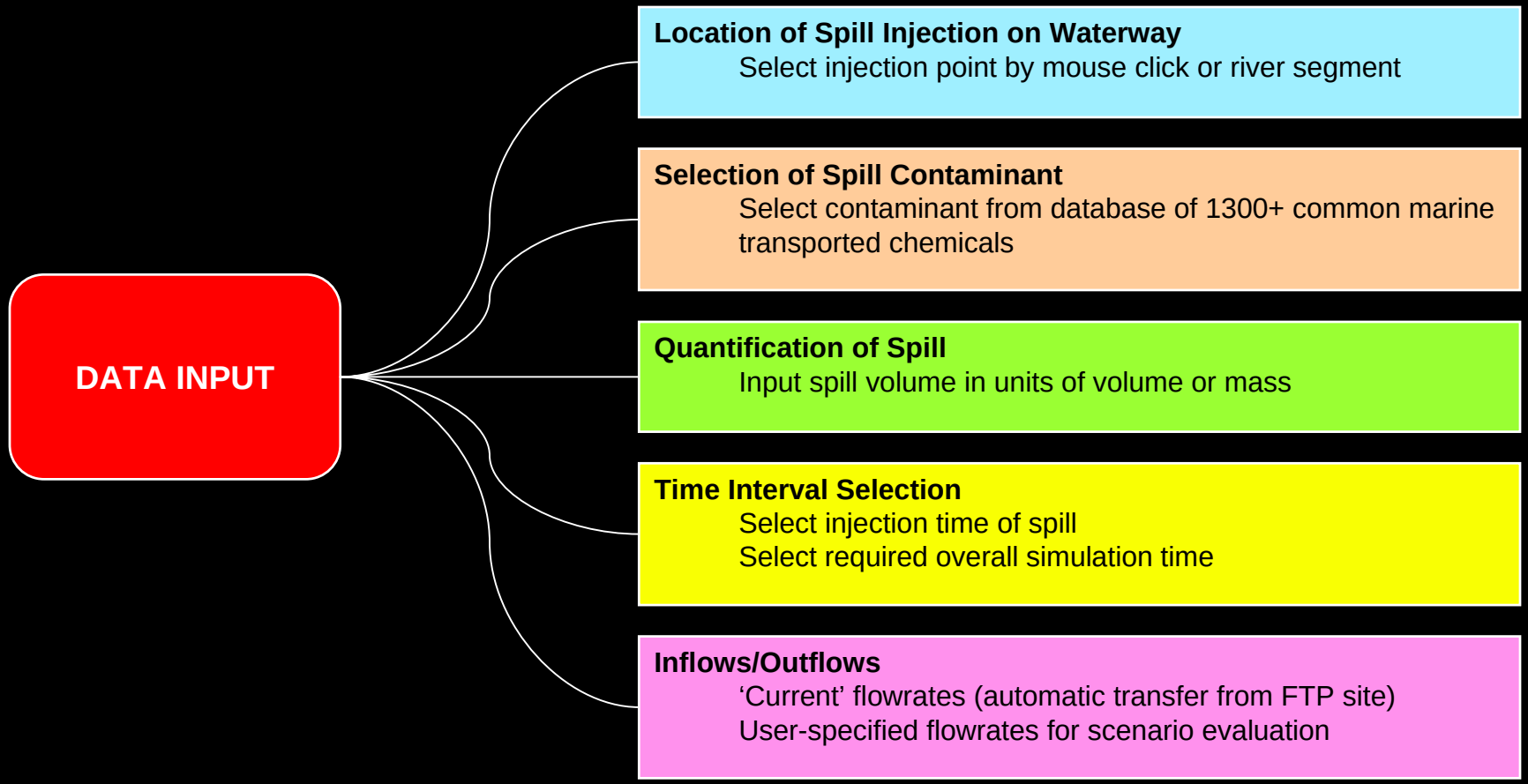


Database Management System

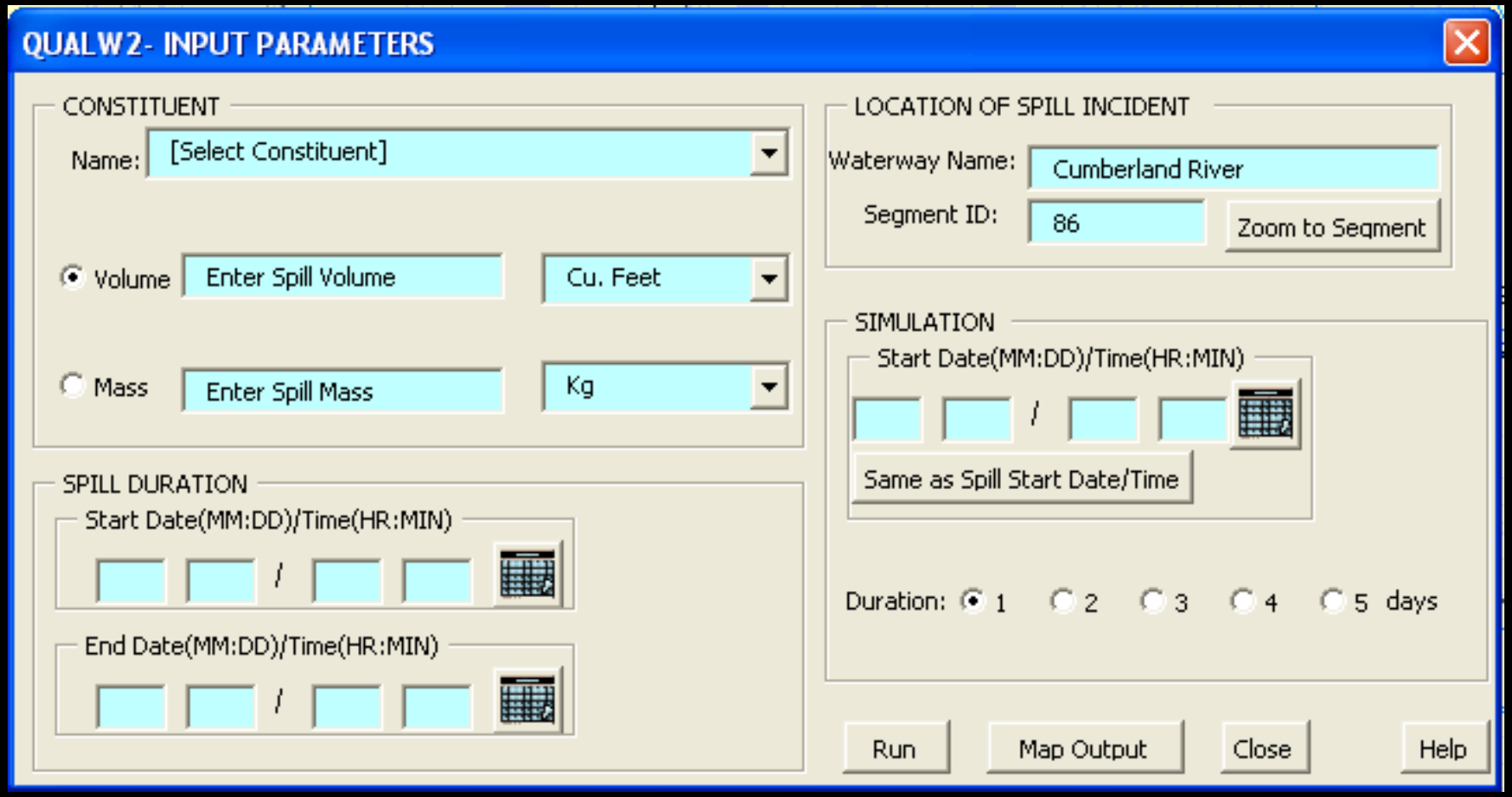
Database Management System stores chemical information and feeds meteorological data to the system.



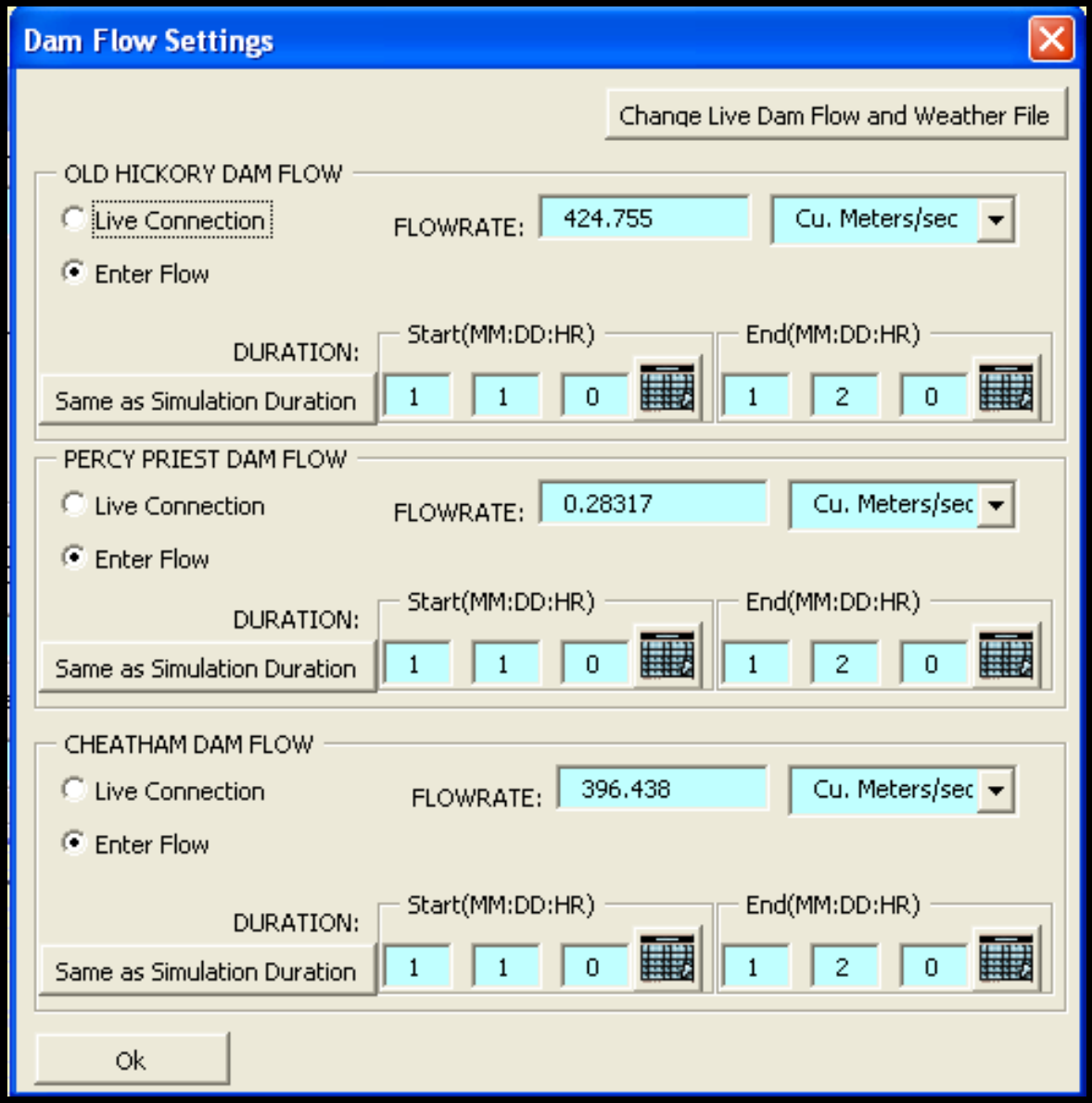
SMIS Data Input



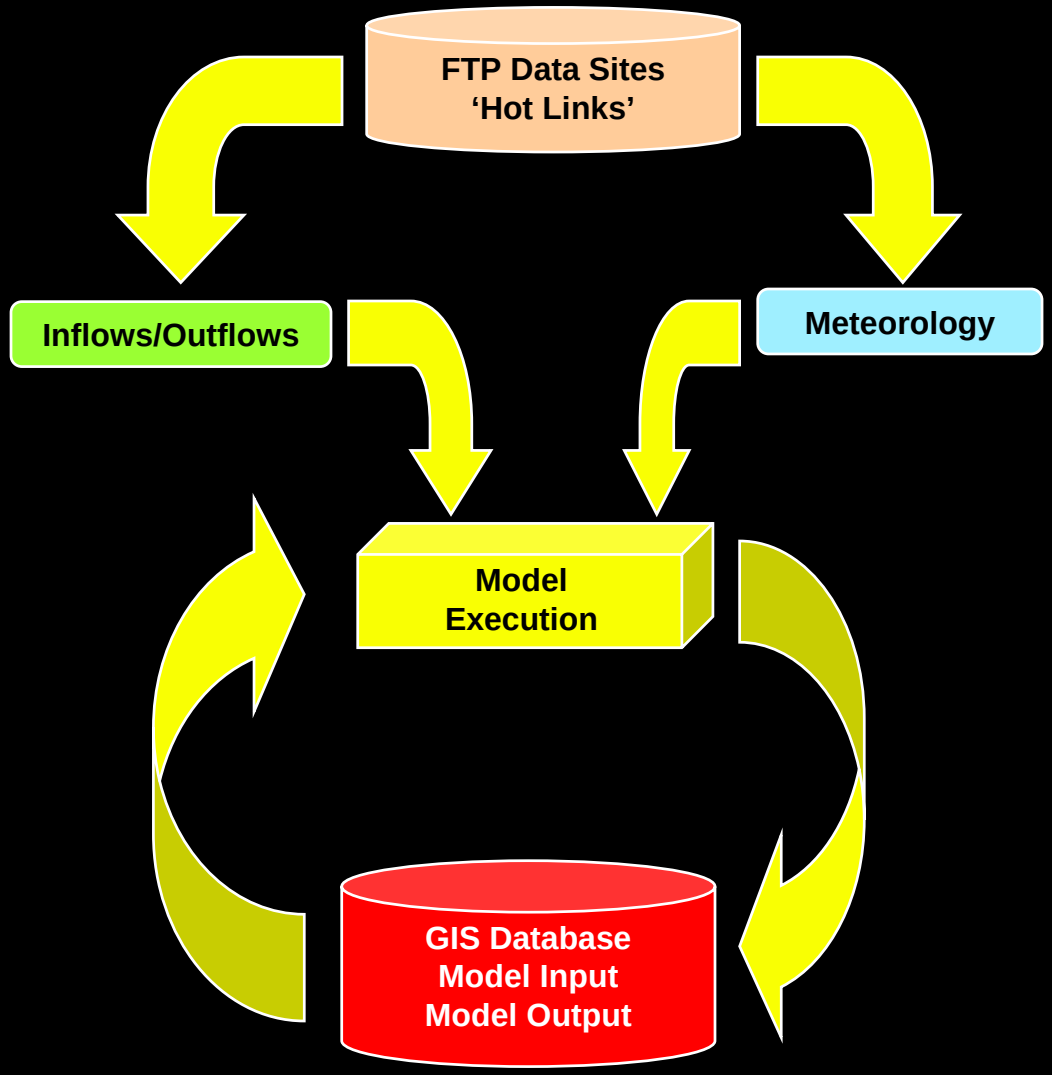
SMIS Data Input



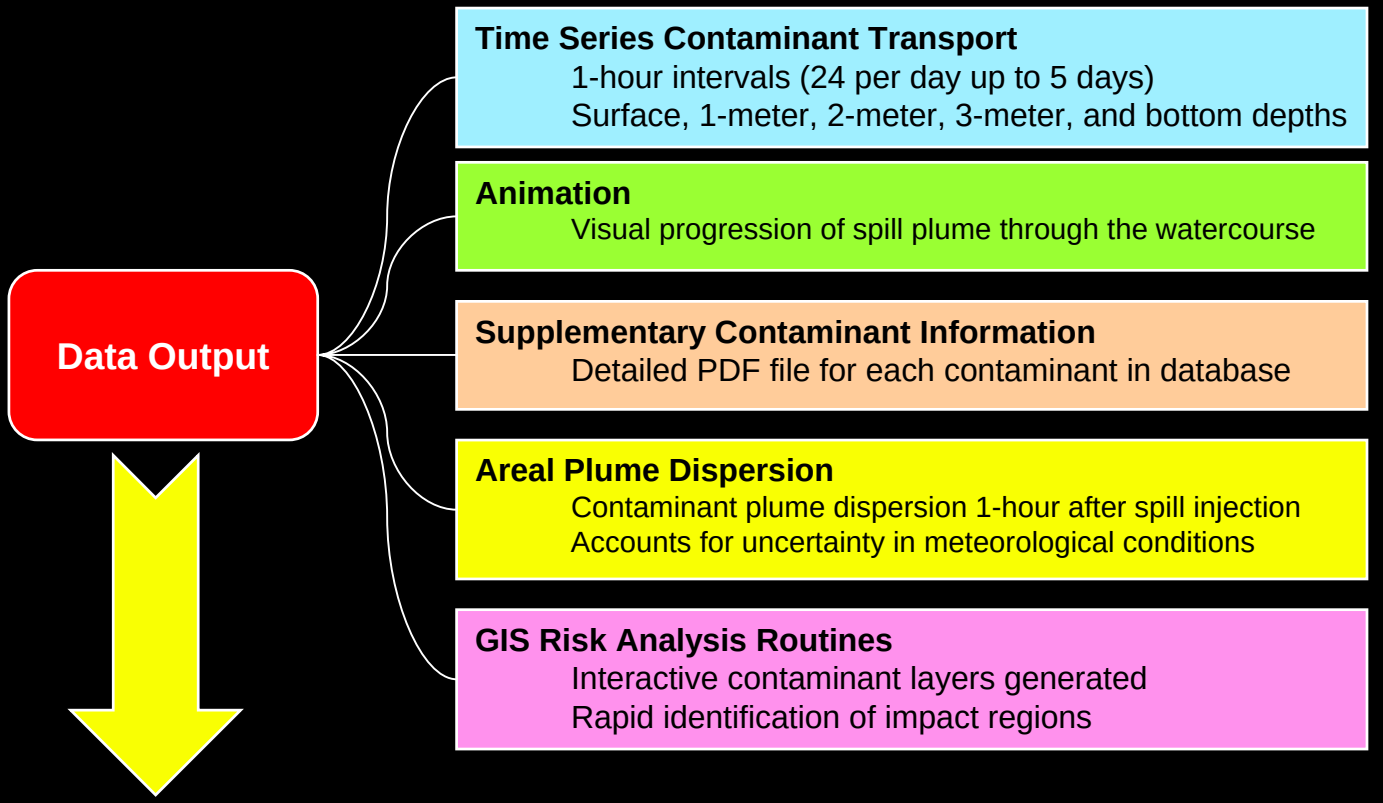
SMIS Data Input



SMIS Model Execution

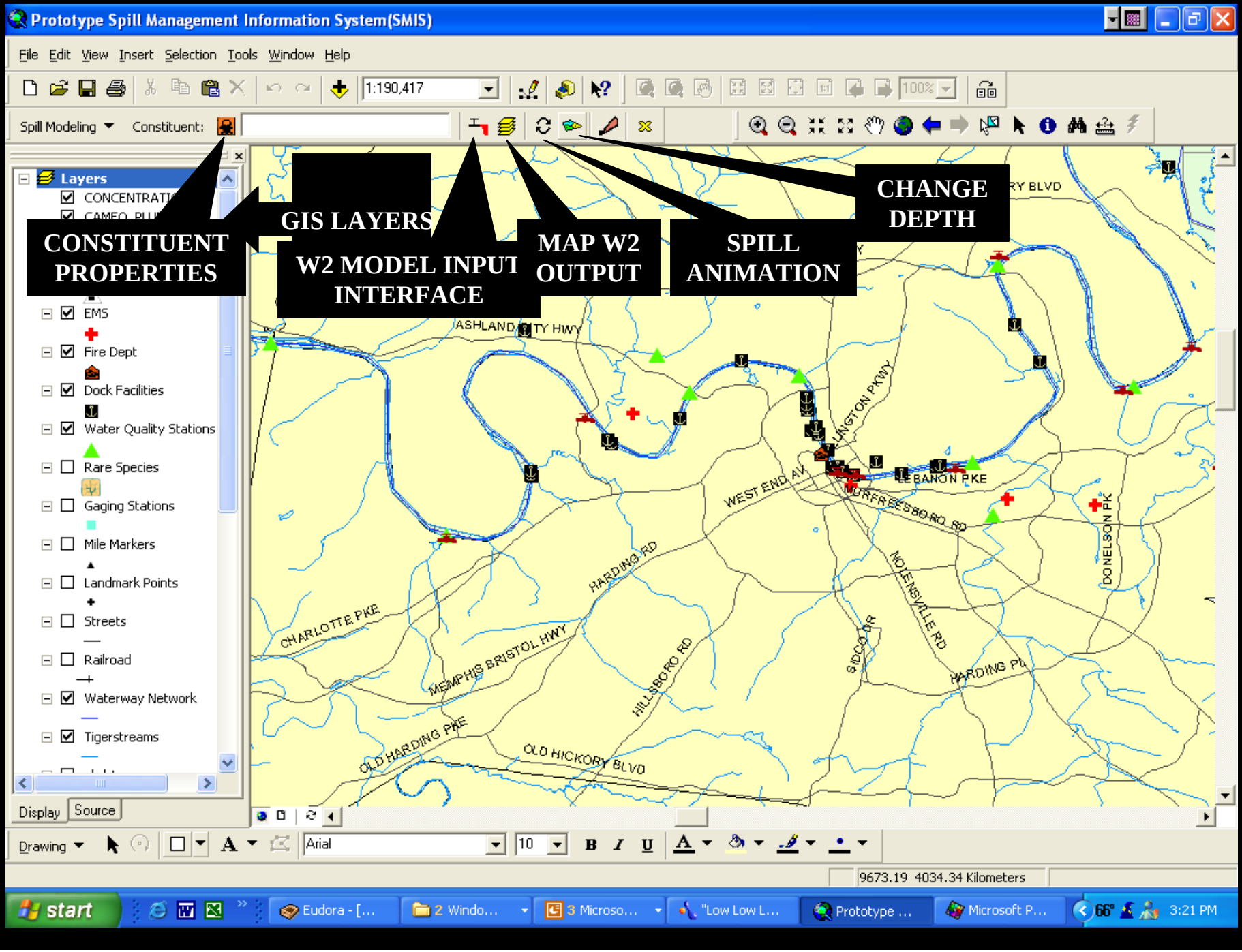


SMIS Output

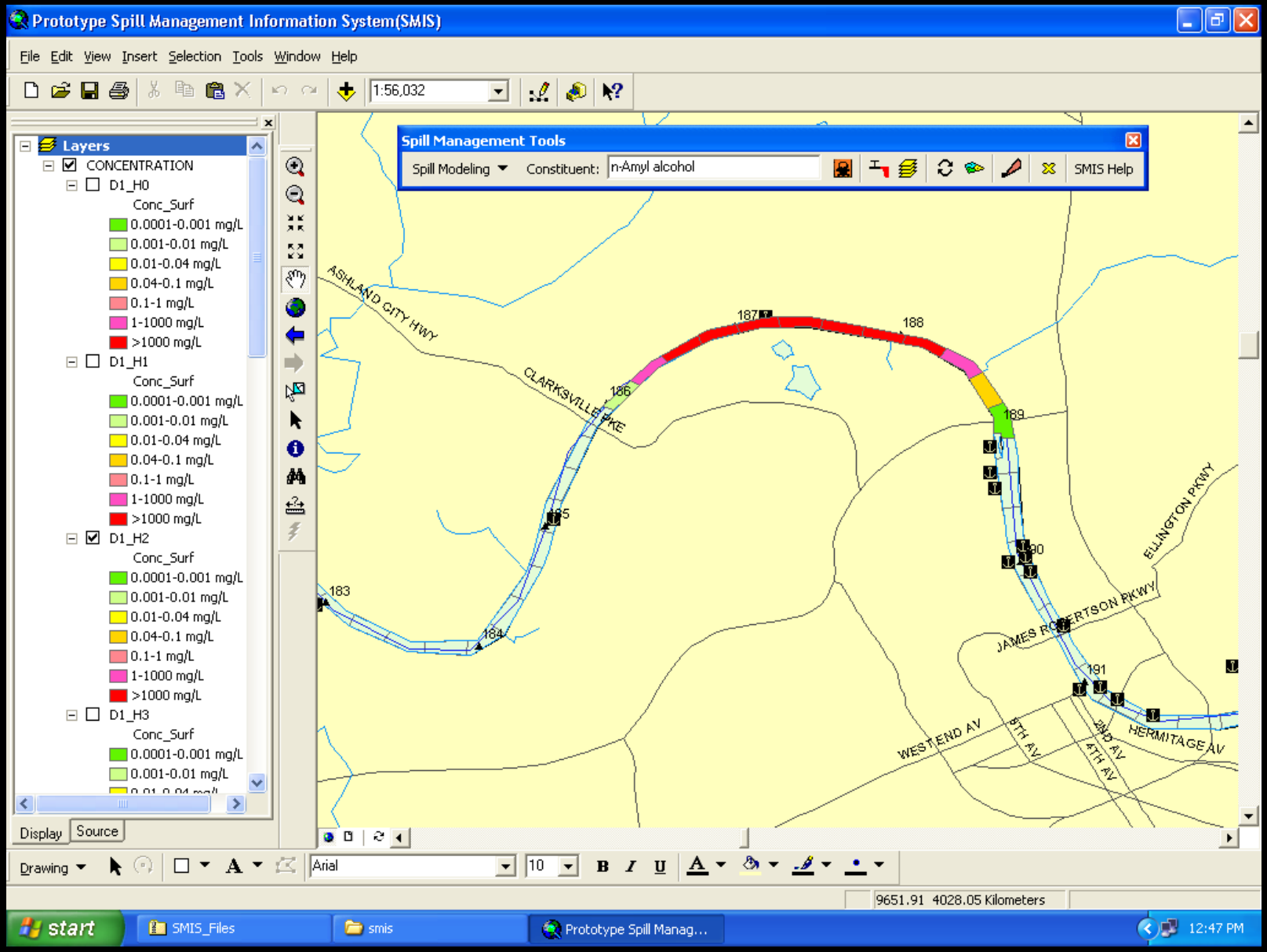


GIS Data Management/Analysis Functions

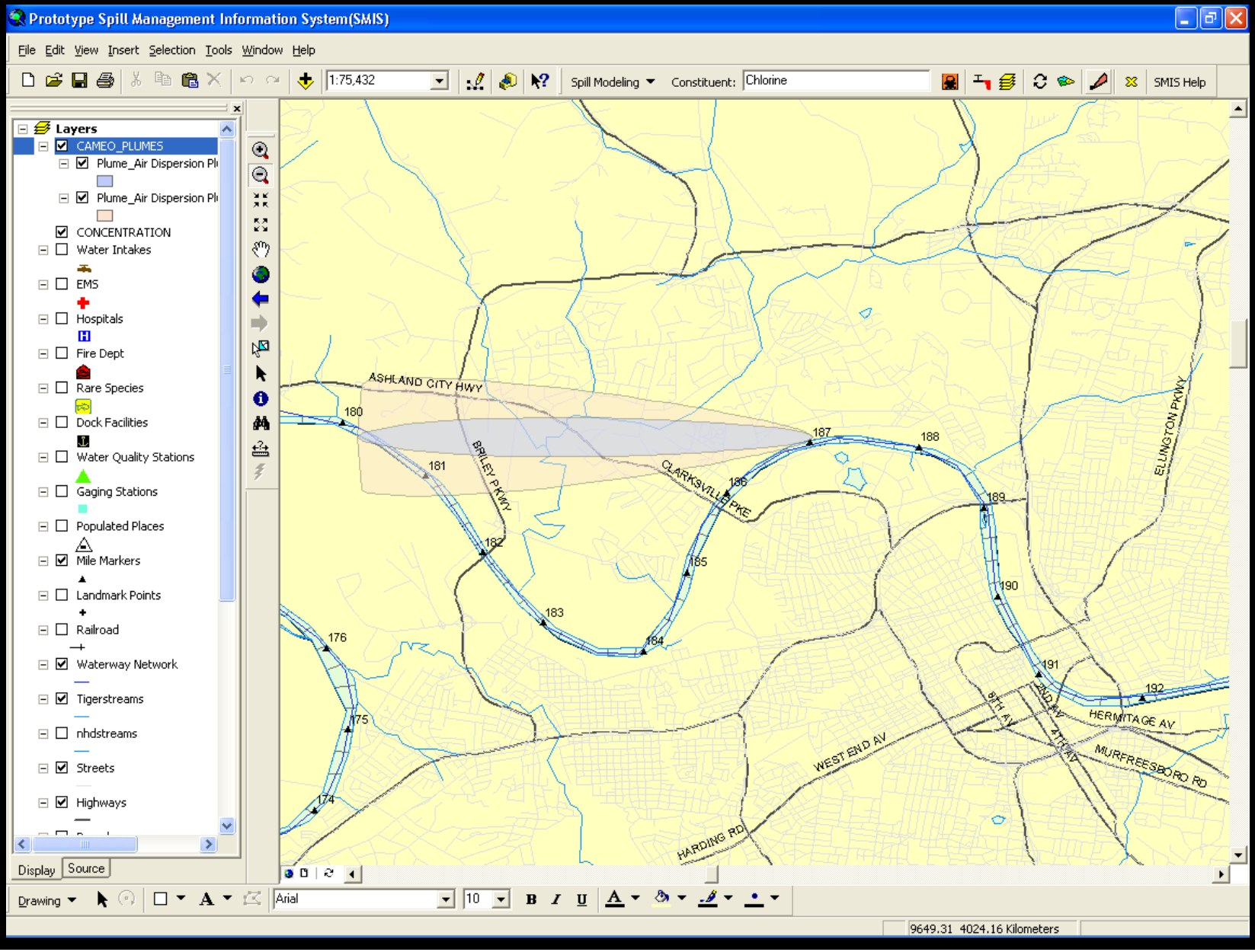
Visualization and translation of study results
Dynamic color graphics for model output
Symbolic representation of study area allowing easy and immediate understanding of basic spatial patters and relationships
Logical/Arithmetic selection of features by time, location, proximity, parameters range
Overlay point-in-polygon, buffering, distance calculation, contouring, and map algebra
Trend analysis, summary statistics, correlation, regression


Prototype Spill Management Information System(SMIS)
File Edit View Insert Selection Tools Window Help
1:190,417
Spill Modeling
Constituent:
CONSTITUENT PROPERTIES
GIS LAYERS
W2 MODEL INPUT INTERFACE
MAP W2 OUTPUT
SPILL ANIMATION
CHANGE DEPTH
Layers
CONCENTRATI
CAMEO PLU
EMS
Fire Dept
Dock Facilities
Water Quality Stations
Rare Species
Gaging Stations
Mile Markers
Landmark Points
Streets
Railroad
Waterway Network
Tigerstreams
Display
Source
ASHLAND CITY HWY
LEBANON PIKE
WEST END AV
MURFREESBORO RD
HARDING RD
CHARLOTTE PIKE
MEMPHIS BRISTOL HWY
HILLSBORO RD
OLD HARDING PIKE
OLD HICKORY BLVD
NOLENSVILLE RD
DONELSON PK
Drawing
Arial
10
9673.19 4034.34 Kilometers
start
Eudora - [...
2 Windo...
3 Microso...
"Low Low L...
Prototype ...
Microsoft P...
66°
3:21 PM

Sample Output – Surface Water Contaminant Dispersion



Sample Output – Air Dispersion



Functionality Summary

•Simulate Release

- Location by mouse click
- Select chemical (1300+)
- Enter quantity (mass or volume)
- Enter spill duration
- Specify simulation duration

•Run Water/Air Quality Models

- CE-QUAL W2
- CAMEO
- Started from GIS interface
- Model fed from chemical database and weather data

•Import and Display Model Results

- Multiple CE-QUALW2 model outputs
  - GIS layers depict stages of spill
  - Animate spill progression
  - Display output at surface, bottom, 1, 2, and 3 meter depths
- Detailed GIS layers for reference, routing, mitigation, and protection

•Perform Mitigation

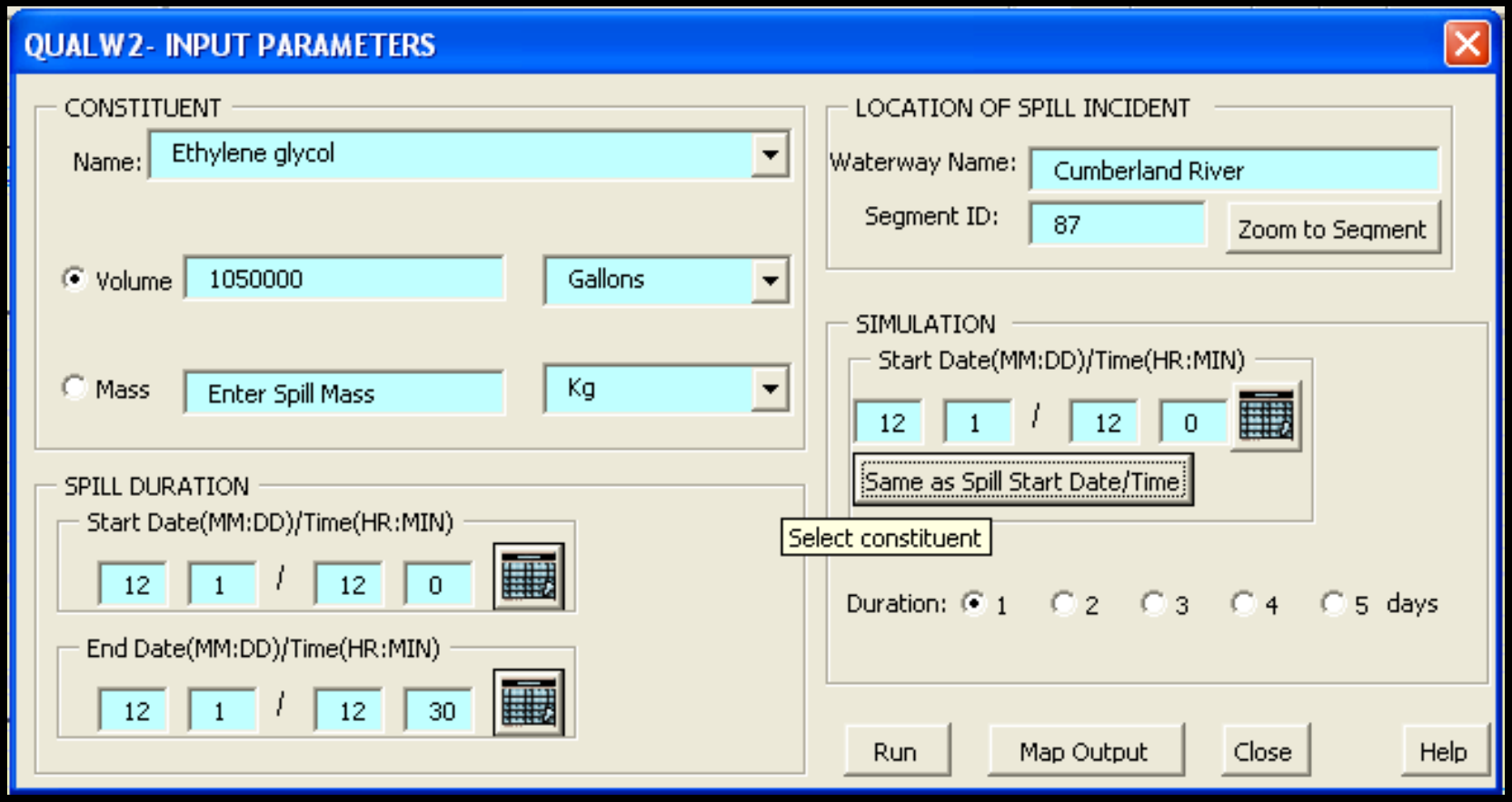
- Locate nearest responders and facilities (using GIS layer contact information)
- Predict where spill will be in future
- Estimate population and ecological exposure
- Perform “what-if” scenarios (e.g., increase/decrease water release from upstream/downstream flow control structures)

Scenario Demonstration

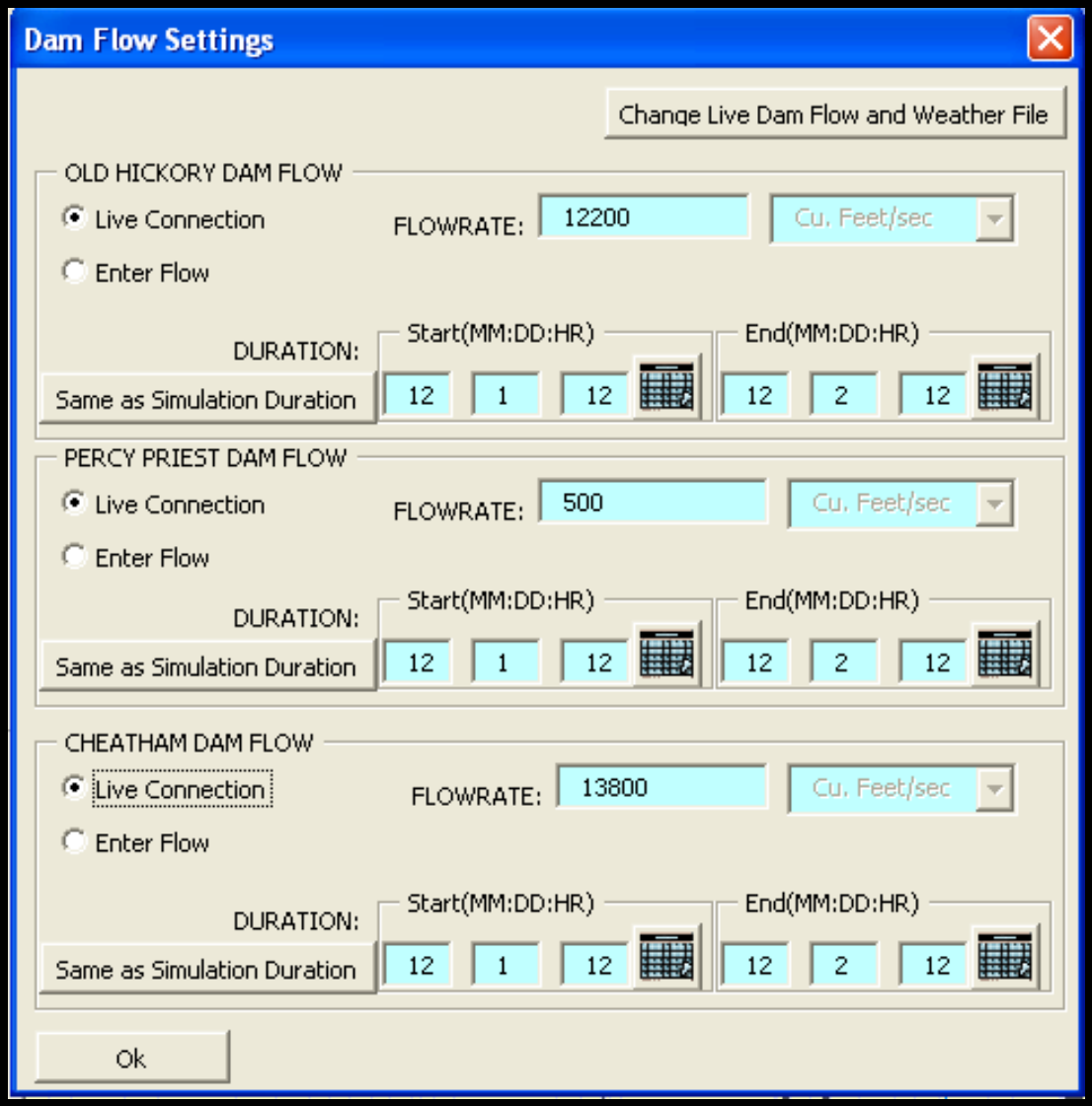
Scenario

- **Location:** Cheatham Reach - RM 194
- **Incident:** Barge Grounding
- **Release:** 25,000 barrels (1.05×10^6 gallons) over 30 minutes
- **Chemical:** ethylene glycol
- **Meteorology:** 10 mph easterly wind, 70^o F, partly cloudy

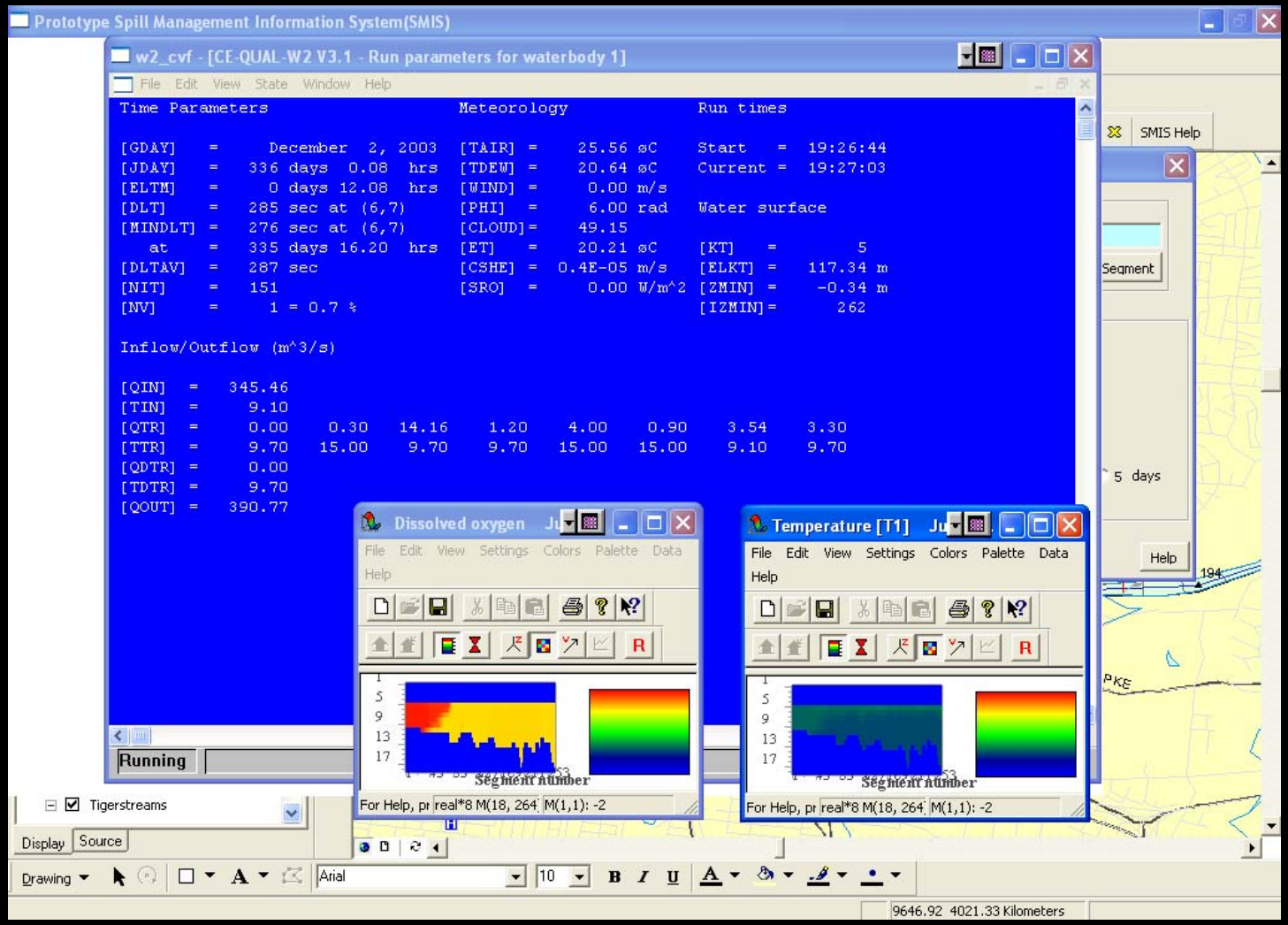
SMIS Input


QUALW2- INPUT PARAMETERS
CONSTITUENT
Name:
Ethylene glycol
Volume
1050000
Gallons
Mass
Enter Spill Mass
Kg
SPILL DURATION
Start Date(MM:DD)/Time(HR:MIN)
12
1
/
12
0
End Date(MM:DD)/Time(HR:MIN)
12
1
/
12
30
LOCATION OF SPILL INCIDENT
Waterway Name:
Cumberland River
Segment ID:
87
Zoom to Segment
SIMULATION
Start Date(MM:DD)/Time(HR:MIN)
12
1
/
12
0
Same as Spill Start Date/Time
Select constituent
Duration:
1
2
3
4
5
days
Run
Map Output
Close
Help

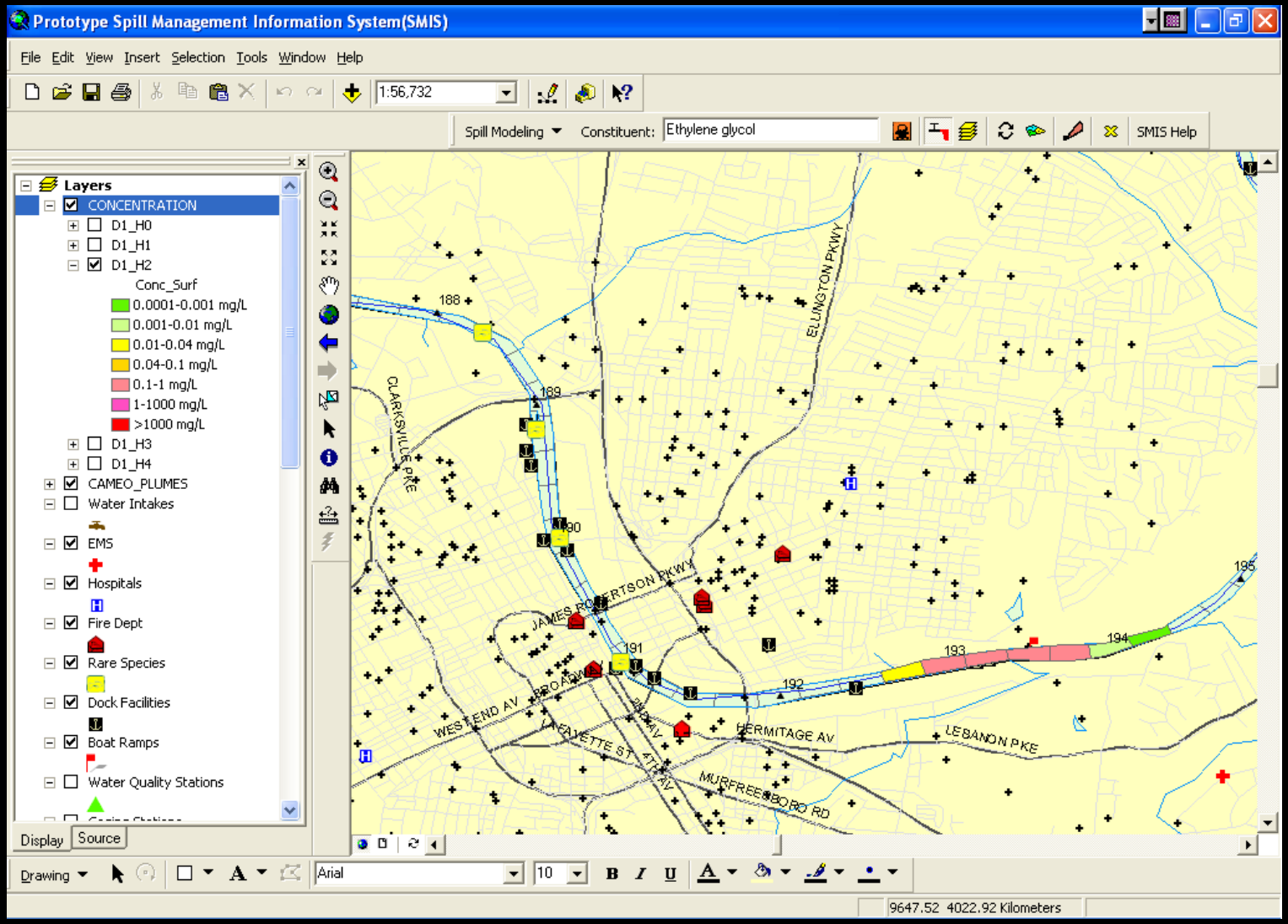
SMIS Flow Settings (Live)



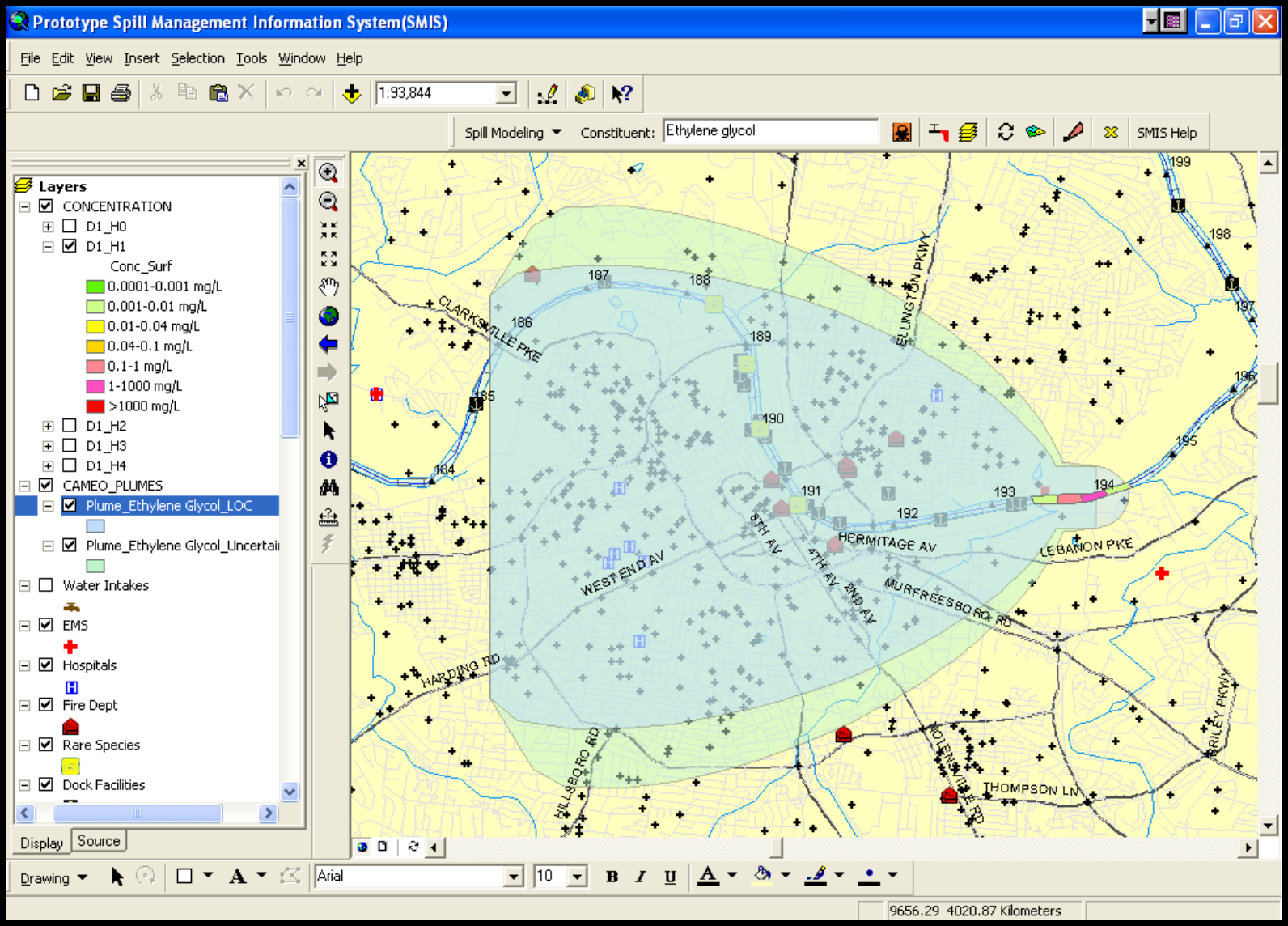
CE-QUAL-W2 Model Execution



Spill Progression – 2 hours



Air Dispersion – 1 hour



Analysis and Abatement Routines

- Animation Tool – toggles on/off layers in succession to create dynamic viewing of spill incident progression
- GIS Risk Analysis Routines – search for sensitive receptors within generated GIS layers (water intakes, endangered species, population centers) and associated attributes (contact numbers, responders, HAZMAT teams)
- Locating Access Points – boat launches, bridges, dock facilities, etc.

Key Project Accomplishments

- **Completed information system design for managing spills on waterways**
- **Deployed state-of-the-art information model, data, and technologies**
- **Established proof of concept that a comprehensive Spill Management Information System is feasible**

Current/Future Directions

- **Utilize existing system for spill management training, planning exercises, and operations**
  - **SMIS exercise with federal/state/local agencies conducted in October 2003**
- **Modular design allows for:**
  - **Application to different waterways**
  - **Use of different prediction models**
  - **Validation of existing models**
- **Development of additional interpretation tools:**
  - **Automate identification of proximate responders and endangered receptors**
  - **Locate vulnerable areas along the waterway**
  - **Rapid queries that identify key facilities & access points**
- **Provide remote Internet capability (with security)**

Potential Applications and Developmental Options

Model enhancements to existing Cheatham Reach may include:

- **Threat zone analysis queries to evaluate where a spill might occur that could threaten particular areas (e.g., endangered species areas, water intakes, schools, businesses, homes, etc.);**
- **Notification systems that can provide contact lists for facilities in affected areas, to include automated calling;**
- **Web-based SMIS to provide portability to first responders in the field (including employment of proper security measures to ensure access to SMIS is limited to authorized users);**
- **Resource analysis to help estimate the level of response needed to adequately address impacts of modeled spills, and the quantity of a particular resource that could be impacted by given spills (e.g., equipment required to isolate a specific endangered species area or water intake zone, such as length of boom, number of transport trucks, number of boats, number of personnel);**
- **Improved reactivity and transport capability within CE-QUAL-W2 to allow for inclusion of the effects of contaminant volatilization, reaction, and/or sorption; and**
- **Improved air dispersion model capabilities (nuclear, biological capability (HPAC))**

Potential Applications and Developmental Options

Transferability of Cheatham Reach SMIS to Similar Waterway Systems:

- **SMIS can be readily adapted to other waterways that can be effectively modeled with CE-QUAL-W2.**
- **Suggested prioritization of work includes other major population centers and/or large volume transportation sectors possessing similar water hydrodynamics to the Cheatham Reach of the Cumberland River.**
- **Required enhancements:**
  - **Incorporation of GIS layers representative of the geographic area of interest;**
  - **Development and calibration of CE-QUAL-W2 model to waterway of interest, to include:**
    - **Waterway bathymetry**
    - **Collection of appropriate flow and water quality data;**
  - **Establishment of 'hot links' to meteorological and water flow data; and**
  - **Installation and training.**

Potential Applications and Developmental Options

Model enhancements for dissimilar waterway systems:

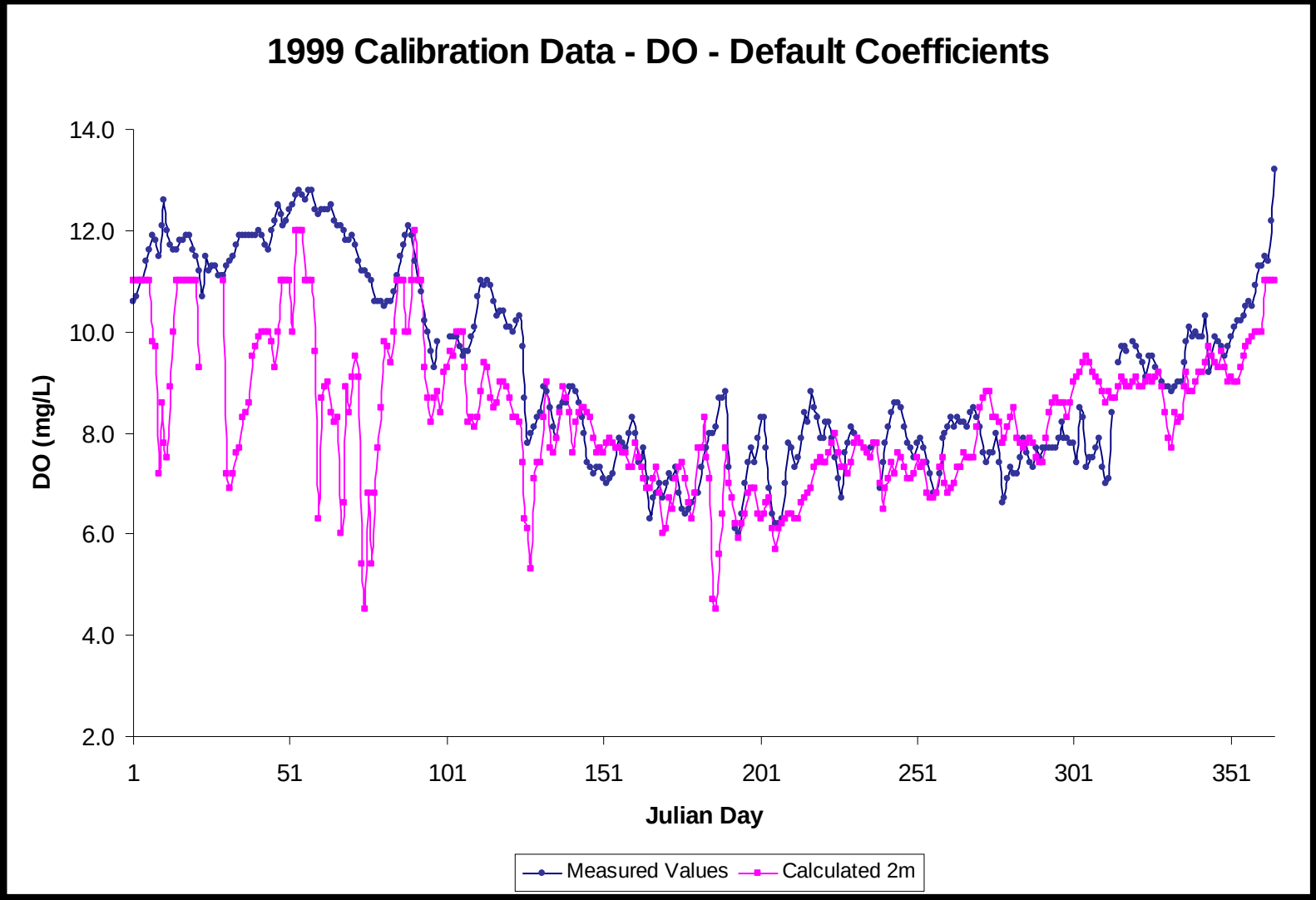
- **Modular framework of SMIS allows employment of additional water quality models to more appropriately model water bodies possessing hydrodynamics that are dissimilar to those modeled by CE-QUAL-W2.**

- **Such systems may include Resource Management Associates 2 (RMA-2) and Resource Management Associates 4 (RMA-4), and others.**

- **Required enhancements:**
  - **Evaluation of the waterway and needs of the client to determine the most appropriate hydrodynamic and contaminant transport models;**
  - **Incorporation of GIS layers representative of the geographic area of interest;**
  - **Development and calibration of the hydrodynamic and contaminant transport models of interest, to include:**
    - **Waterway bathymetry**
    - **Collection of appropriate flow and water quality data;**
  - **Design and implementation of applications module to activate and integrate model functionality within SMIS;**
  - **Establishment of 'hot links' to meteorological and water flow data; and**
  - **Installation and training.**

Questions?

CE-QUAL-W2 Calibration



CE-QUAL-W2 Calibration